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The Filter Feeders *Hydropsyche angustipennis* and *H. pellucidula* (Trichoptera: Hydropsychidae) in a Northern German Lowland Stream: Microdistribution, Larval Development, Emergence Pattern, and Secondary Production

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With 5 Figures and 1 Table

Key words: Microdistribution, larval development, secondary production, emergence pattern, *Hydropsyche angustipennis*, *Hydropsyche pellucidula*, lowland stream, lake outlet

Abstract

Microdistribution, life history, and secondary production of two species of Hydropsychidae were studied in the outlet of the eutrophic Lake Belau (Schleswig-Holstein, Northern Germany). A total of 3,647 larvae were collected at 11 sampling sites with a box sampler: 1,995 larvae of *Hydropsyche angustipennis* and 1,652 larvae of *H. pellucidula*. 133 adults of *H. angustipennis* and 130 adults of *H. pellucidula* were caught by 12 swimming emergence traps.

Annual mean hydropsychid density in the stream was 202 ind. m^{-2}. Highest densities were observed at gravelly substrates with 1,080 ind. m^{-2} of *H. angustipennis* and 780 ind. m^{-2} of *H. pellucidula*. At sites with fine sand, sand, and peat less than 11 ind. m^{-2} of both species were found. Both species were univoltin and during almost the entire year larvae of the instars 3 to 5 appeared in the stream. The main growth of *H. angustipennis* was observed from May to June, just before the larvae emerged. Looking at *H. pellucidula* two growth phases could be identified, the first approximately in the fourth month of life (September) and the second between May and August of the following year.

During 10 months the larvae of *H. angustipennis* showed an almost constant mean individual weight of 0.4 to 0.5 mg DM (dry mass) and the larvae of *H. pellucidula* of about 1.5 mg DM. In the investigated stream mean annual biomass of *H. angustipennis* was 115 mg DM m^{-2} and production 484 mg DM m^{-2} yr^{-1} (P/B = 4.2). *H. pellucidula* had a mean annual biomass of 231 mg DM m^{-2} and a production of 428 mg DM m^{-2} yr^{-1} (P/B = 1.9). Both species emerged from May to September with maxima in May and August. Biomass of emerged *H. angustipennis* was 94 mg DM m^{-2} and of emerged *H. pellucidula* 116 mg DM m^{-2}. The ratio for emerged biomass to the larval secondary production E/P amounted to 19.3% for *H. angustipennis* and 27.0% for *H. pellucidula*.

Introduction

Hydropsyche angustipennis (CURTIS, 1834) and *H. pellucidula* (CURTIS, 1834) belong to the most common species of Trichoptera in the lowland of northern Germany (BÖTTGER & POEPPERL 1990, 1992a, 1992b). As filter feeders they mainly live in streams with a high quantity of seston, particularly in larger streams as well as lake outlets (POEPPERL 1992; POEPPERL & BÖTTGER 1991; STATZNER 1979). But only little is known about the life cycle of both species in these lowland streams. During investigations of the emergence pattern of these two species two maxima were often observed over the year (i.e., MATZDORF 1964; POEPPERL & BÖTTGER 1991). After HILDREW & EDINGTON (1979) and EDINGTON & HILDREW (1981) the development of the larvae of *H. pellucidula* is accomplished within the first four months of life. During the following eight months the individuals appear in the last (fifth) instar. The retarded emergence pattern appearing subsequently is hardly established until today (cf. SCHUHMACHER 1970). In the search of a possible reply of such questions the benthic biocoenosis was investigated simultaneously with collecting of emerging adults.

In the literature a combination of both methods was only rarely taken into consideration up to now (BÖTTGER & POEPPERL 1992b; JACKSON & FISHER 1986; SPEIR & ANDERSON 1974). Based on this procedure it is expected to give an answer to further questions, which were raised in the literature already since decades (ILLIES 1971, 1972, 1974, 1975, 1983; cf. JACKSON & FISHER 1986; SPEIR & ANDERSON 1974). ILLIES (1971, 1972) popularized the emergence method as a means to assess the productivity or at least to gain an insight into productivity processes. But he did not provide data that could be used to elucidate a relationship between annual benthic production and emergence. Only very few studies deal with the questions, what a proportion emergence has in the total secondary production of merolimnic insects (JACKSON & FISHER 1986). Based on the results of four species of Simuliidae SPEIR & ANDERSON (1974) propagate that, if the relationship is applicable to other aquatic insects, a comparatively simple and accurate method of estimating benthic production could be developed from emergence traps data. Because of this the emergence data of *Hydropsyche angustipennis* and *H. pellucidula* are combined with the benthic secondary production and are considered as an aspect of production biological research.

Study area

The outlet of Lake Belau is situated 30 km south of Kiel (Schleswig-Holstein, Northern Germany) at the outer margin of the Weichselian (= Wisconsinan) glaciation (54° 06' N, 10° 15' E). The discharge of the stream (0.08 to 0.6 $m^2 s^{-1}$) is mainly regulated by a water-mill. The current velocity ranged from 0.05 to 0.6 m s^{-1}, and the water level showed a variation of up to 0.4 m. The straighten stream has a constant width of 6 m and flows through cultivated farmland. After a distance of 1.9 km the stream flows into Lake Stolpe (Fig. 1).

Chemical and physical properties of the water are strongly influenced by Lake Belau, an eutrophic, mainly dimictic, and holomictic bicarbonate lake (MÜLLER 1981). High amplitudes in temperature, conductivity, pH, N-, and P- concentrations measured over the year are caused mainly by the biological activities in the eutrophic lake. Details of the biological, hydrochemical, and hydrophysical regime are given in ASSHOFF et al. (1991), POEPPERL (1992, 1996, 1999), POEPPERL et al. (1995), POEPPERL & WITZEL (1991), and SCHERNEWSKI (1992).

Eleven sampling sites (AS I to AS XI) that appeared to be most characteristical for the stream were selected and numbered following the direction of the water flow (Fig. 1). Sampling sites AS I and AS II are situated near the upstream Lake Belau. They are dominated by fine substrates with a high portion of Unionid shells. In the middle course of the stream samples were taken at characteristic areas that represented the different habitats: Stony (AS III), gravelly (AS IV), sandy (AS V) and peaty (AS VI) habitats as well as habitats with dense stocks of macrophytes (mainly *Elodea canadensis*) and areas of mud and fine sand (AS VIII). Before entering Lake Stolpe the stream flows through a small forest. At sampling site AS IX there was a high portion of fine sand. AS X was characterized by gravel on a sandy bed and AS XI by a uniform mixture ranging from stone to fine gravel on a sandy-gravelly bed.

Material and Methods

Sampling methods

Hydropsychid larvae were sampled with a metal box sampler (square area of 500 cm^2, height of 38 cm) as described by HYNES (1971) and STATZNER (1979, 1981a). Altogether 11 sampling sites were investigated every four weeks from October 1988 to March 1990. The upper layer (> 5 cm) of the substrate together with the or-

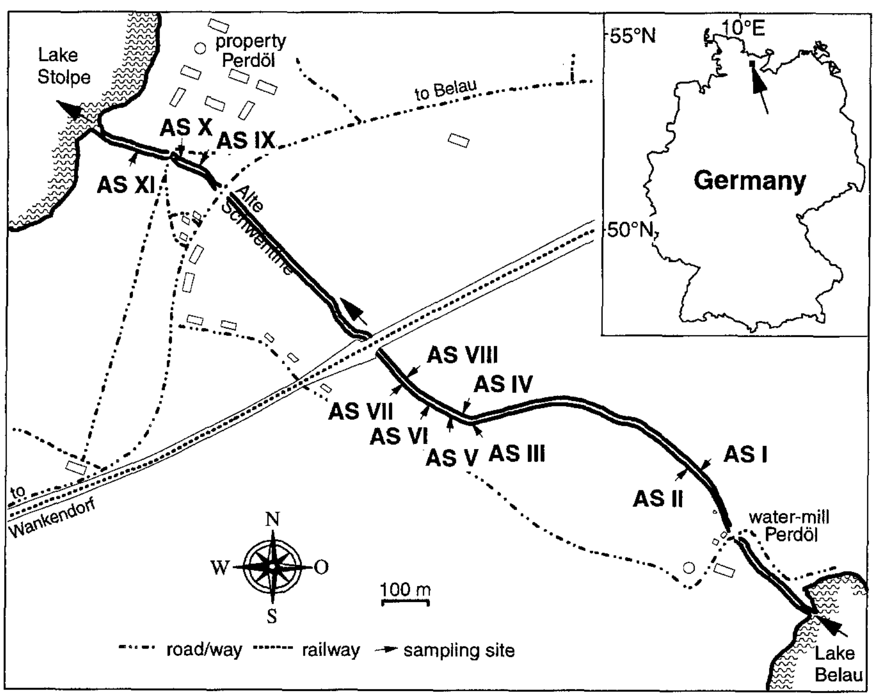

Fig. 1. Course of the outlet of Lake Belau ('Alte Schwentine') with sampling sites (AS I to AS XI). See text for further informations. (After POEPPERL 1996).

ganisms was sampled using a hand net (POEPPERL 1992). Sampling with a box sampler reduces the selectivity of the methods (ALBRECHT 1961; CUMMINS 1962; HYNES 1971; MACAN 1958; STATZNER 1979).

Emergence time and intensity of the hydropsychids in the outlet of Lake Belau were investigated from 10th April to 8th November 1989. At characteristical substrates of different stream sections 12 emergence traps were installed and usually inspected three times a week. The swimming emergence traps consisted of a wooden scaffold covered by a 0.25 mm mesh net. The area of the traps covered 0.33 m^2 stream surface.

In this study quantitative data of secondary production as well as biomass of insects emerging from the stream were calculated for the year 1989.

Laboratory methods

Benthos samples were stored in a temperature-controlled and aerated aquarium until sorting out, which was done within 2 to 4 days. Larval Hydropsychidae were carefully sorted out by hand after being washed in a sieve of 500 µm mesh size (see BARBER & KEVERN 1974). Animals were preserved in 70% ethanol. Instar 1 and 2 could not be identified to the species level. Species were identified according to MACAN (1973), MALICKY (1983), and STATZNER (1976).

In the field adult Hydropsychidae were preserved in 70% ethanol separately for each emergence trap and each sampling date. For the determination of species TOBIAS & TOBIAS (1981), MACAN (1973), and TOBIAS (1972a, 1972b) was employed.

Calculation of population biomass and production

Width of the head capsule of all larvae was measured. Individual weights of length classes were determined as dry mass (DM). Larval population biomass was calculated by using a length-weight relationship (POEPPERL 1998). Biomass of adults caught in the emergence traps was calculated based on gender-specific individual weights of species (listed in POEPPERL 1987).

Series of size distributions of each sampling date give informations on life-span, reproduction, and growth of both *Hydropsyche* species. When there is a synchronous emergence pattern (respectively synchronous hatching) and a similar growth of all individuals different generations can be distinguished as cohorts in the size frequency diagramm. Assuming a normal length distribution within a cohort the single lenght classes can be related to specific generations or larval stages. Shifting these cohorts with time growth, period of reproduction and emergence, and the life-span of a generation can be estimated. Afterwards the abundance was calculated for each generation, from which information of mortality in the single life stages can be infered. The Allen-method (ALLEN 1951; MANN 1971) was employed to calculate production because it is known to be quite unproblematic (LAPCHIN & NEVEU 1980) if the different cohorts can be distinguished (BENKE 1993).

Results and Discussion

Two species of the genus *Hydropsyche* PICTET, 1834 live in the outlet of Lake Belau: *H. angustipennis* and *H. pellucidula*. In this study quantitative data are calculated for the year 1989 and for a square metre of stream bed as well as for different substrates. Calculation of abundance, biomass and secondary production of the stream take into account the proportion of areas of the different substrates.

Microdistribution

A total of 3,647 larvae were collected in the quantitative box samples, 1,995 larvae of *Hydropsyche angustipennis* and 1,652 of *H. pellucidula* (Table 1). The annual mean hydropsychid density of the stream average, which sums up the different substrates found throughout the whole stream bed, was 202 ind. m^{-2}. Both species prefer stony and gravelly substrates (Fig. 2). Highest densities were observed at AS X with 1,080 ind. m^{-2} of *H. angustipennis* and 780 ind. m^{-2} of *H. pellucidula*. At sandy and muddy substrates only a few individuals were found, mainly living on dead wood and leaves. At the sandy substrate of AS V no *Hydropsyche*-larvae were found. At the fine sand of AS IX and the peat of AS VI 7 resp. 11 ind. m^{-2} of *H. angustipennis* and 0 resp. 6 ind. m^{-2} of *H. pellucidula* were caught.

The preferences of both species for stony and gravelly substrates have been described before by e.g. BURKHARDT (1983, 1986), CASPERS et al. (1977), DUDGEON (1997), HIGLER & TOLKAMP (1983), POEPPERL (1992), SCHUHMACHER (1970), STATZNER (1981b), TOLKAMP (1980), and WIBERG-LARSEN (1980). According to STATZNER (1981b) abundance is related well to the hydraulic stress, effective on the animals. The lack of a third species in the outlet of Lake Belau, *H. siltalai*, usually present in natural streams of Schleswig-Holstein (cf. BRINKMANN 1985, POEPPERL & BÖTTGER 1991), can be connected to the artificially reduced current velocity in the afternoons and at night because this species needs a continuous current velocity of 0.15 to > 1.0 m s^{-1} (EDINGTON 1968). *H. angustipennis* and *H. pellucidula* however can also live in streams with lower current veloci-

Table 1. Number of individuals caught, mean annual benthic biomass, and secondary production as well as emerged biomass of *Hydropsyche angustipennis* and *H. pellucidula* in the Northern German lowland stream 'Alte Schwentine'.

		H. angustipennis	*H. pellucidula*
Benthos:			
Individuals	[ind. caught]	1,995	1,652
Biomass B	[mg DM m^{-2}]	115.4	231.5
Production P	[mg DM m^{-2} yr^{-1}]	484.4	428.4
Emergence:			
Individuals	[ind. caught]	133.0	130.0
Biomass E	[mg DM m^{-2} yr^{-1}]	93.7	115.5
P/B		4.2	1.9
E/P	[%]	19.3	27.0

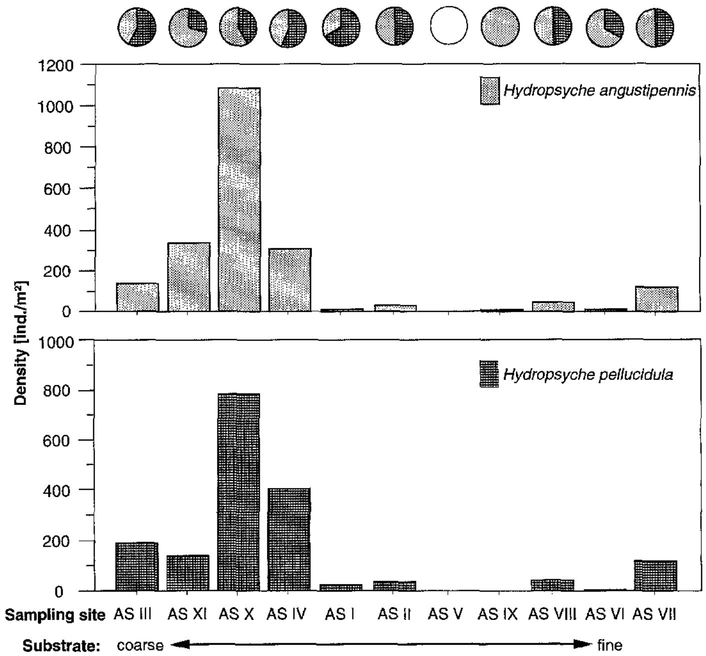

Fig. 2. Annual mean density of *Hydropsyche angustipennis* and *H. pellucidula* and percentage in the number of both species of Hydropsychidae (cycles in the top) at the sampling sites AS I to AS XI.

(1976), ELLIOTT (1968), FLÖSSNER (1982), HILDREW (1978), HILDREW & EDINGTON (1979), and XIANG et al. (1984). The first and second instars could not be distinguished, third instar individuals of both *Hydropsyche angustipennis* and *H. pellucidula* occurred in the samples from end of June. Then, individuals of the third to fifth (i.e. final) instar (Fig. 3) were caught during the whole year.

During 10 months the larvae of *H. angustipennis* show an almost constant mean individual weight of 0.4 to 0.5 mg DM (dry mass) and the larvae of *H. pellucidula* of about 1.5 mg DM; this is similar to the results of CÉRÉGHINO et al. (1997) for *H. instabilis*. Mean individual mass as well as the size-frequency distribution (head capsule width) indicated that a larger proportion of the *H. angustipennis* larvae than of *H. pellucidula* belong to the third instar. *H. angustipennis* has a main growth period from May to June, shortly before emerging (comp. CÉRÉGHINO et al. 1997). Looking at *H. pellucidula* two growth periods can be identified (Fig. 4): The first period in the first four months of life (September) and the second one from May to August of the following year. The importance of the almost one year old larvae increases when taking into account that the older larvae pupate and therefore are not considered in the pattern of growth.

A corresponding pattern can be observed when looking at the mortality. Almost during the entire life no periods of higher mortality can be observed. A clear decrease in the number of individuals is recognizable only in the period of pupation.

ties (PHILIPSON 1957), due to a differing respiratory regime (SCHUHMACHER & SCHREMMER 1970; PHILIPSON & MOOREHOUSE 1974).

Larval development

In the outlet of Lake Belau both *Hydropsyche* species are univoltin, as described for other streams by BADCOCK

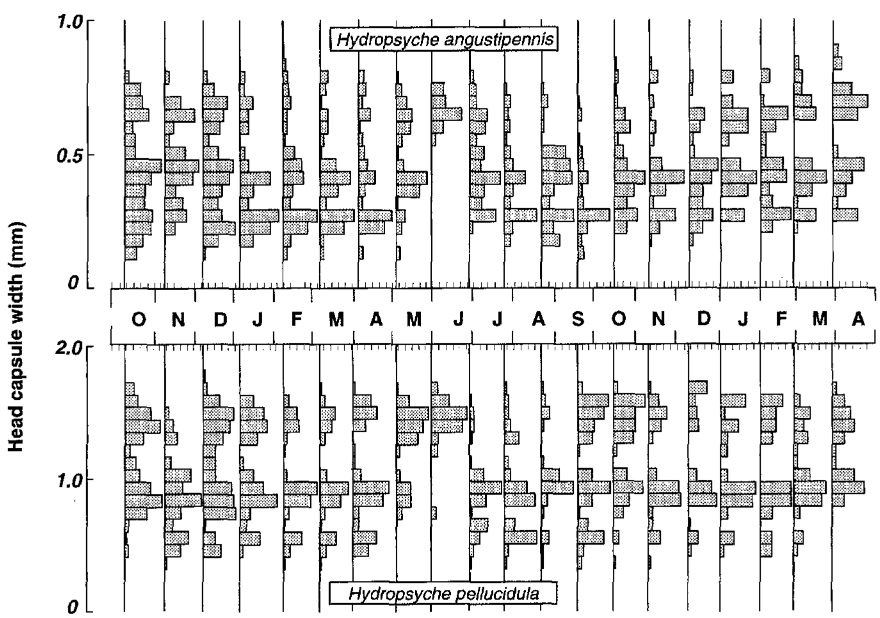

Fig. 3. Percentage size-frequency distribution (head capsule width) of *Hydropsyche angustipennis* (n = 1,995 individuals) and *Hydropsyche pellucidula* (n = 1,652 individuals) in the outlet of Lake Belau from October 1988 to March 1990.

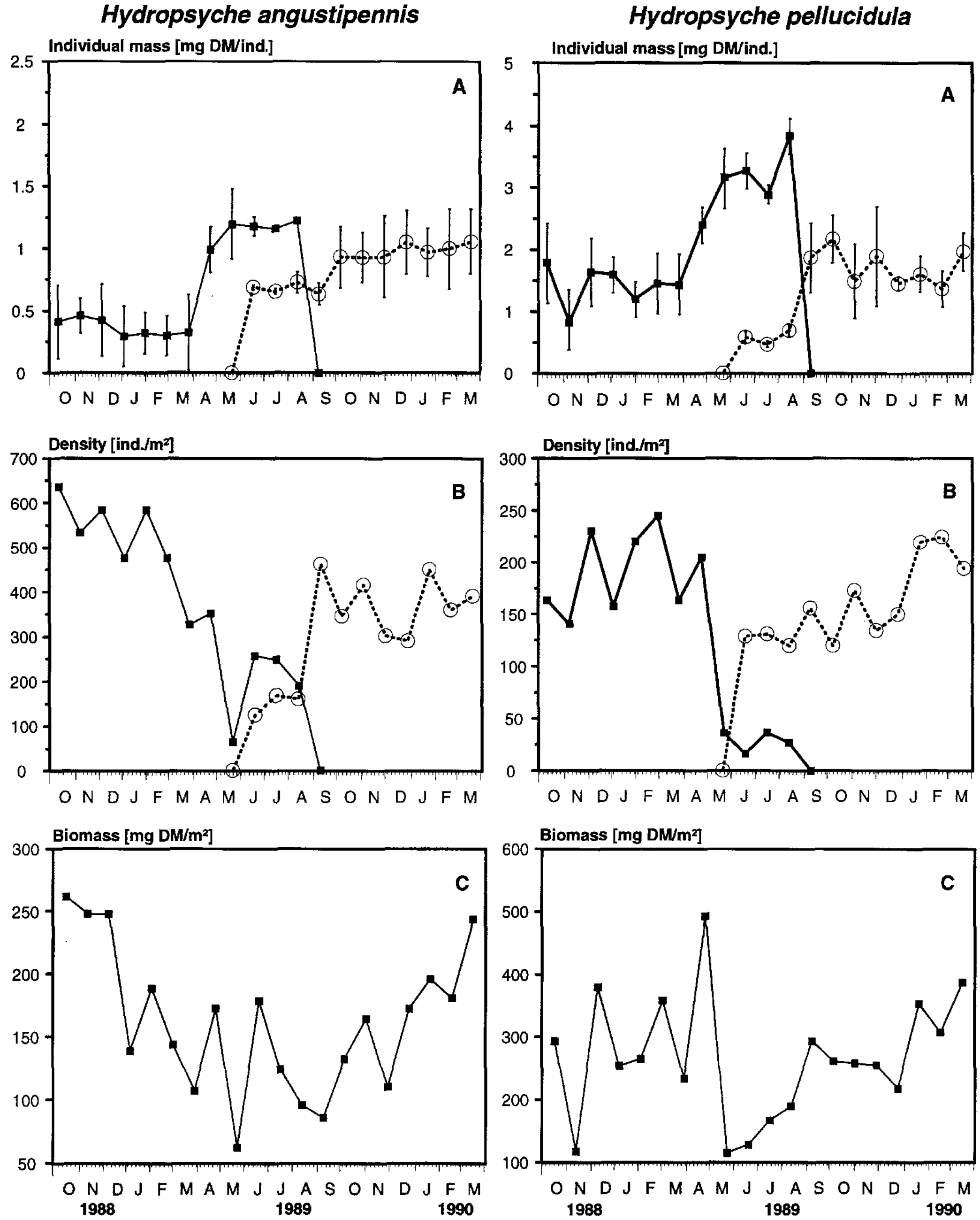

Fig. 4. Growth (A), density (B), and annual course of biomass (C) of *Hydropsyche angustipennis* (n = 1,995 individuals) and *H. pellucidula* (n = 1,652 individuals). Error bars are ±1 SE. Generations are indicated by different symbols.

Biomass and secondary production

Annual mean dry mass of *H. angustipennis* amount to 115 mg m^{-2}, annual production to 484 mg m^{-2} resulting in a P/B-ratio of 4.2 for 1989 (Table 1). *H. pellucidula* has a mean dry mass of 231 mg m^{-2}, a production of 428 mg m^{-2} and a P/B-ratio of 1.85. STATZNER (1979) calculated a P/B-ratio of 3.1 for *H. angustipennis* and 2.4 for *H. pellucidula* in another northern German lake outlet. For *H. angustipennis* FLÖSSNER (1976, 1982) determined a ratio of 4.3 in the river Saale and 4.6 in the river Ilm (Thuringia). CASPERS (1978) reported a ratio of 3.0 for *H. instabilis*.

As facultative net-spinners (SCHUHMACHER 1970; SCHRÖDER 1976; FEY & SCHUHMACHER 1978) larvae of *Hydropsyche* belong to the functional group of filter feeders (CUMMINS 1973; SCHRÖDER & STREIT 1983), but also live as scrapers, collectors or predators (SCHUHMACHER 1970; SCHRÖDER 1976; XIANG et al. 1984). During winter, when the water temperature is less than 11 °C, the larvae do not spin nets and mainly feed as scrapers to satisfy the needs of their reduced metabolism (XIANG et al. 1984). Accordingly, the biomass in particular of *H. pellucidula* increased from end of May to August (cf. HILDREW & EDINGTON 1979, EDINGTON & HILDREW 1981).

Emergence pattern

133 individuals of *Hydropsyche angustipennis* and 130 individuals of *H. pellucidula* were caught in the 12 emergence traps during 1989. Both species emerge from May to September (Fig. 5). According to the size-frequency distribution (Fig. 3) of the larvae of *Hydropsyche angustipennis* and *H. pellucidula*, the emergence pattern shows also two maxima, a first one in the end of May and a second one in the end of August. POEPPERL & BÖTTGER (1991) observed also two maxima at both species in the Kossau, another stream in the lowlands of northern Germany. The emergence pattern seems to reflect the individual larval stages which pupate at different periods of time which provokes a corresponding retarded emergence.

During the investigation period biomass of adults of *H. angustipennis* caught by emergence traps was 94 mg DM m^{-2} and of emerged *H. pellucidula* 116 mg DM m^{-2}. These value combined with the annual larval secondary production of 484 resp. 428 mg DM m^{-2} yr^{-1} yields a relationship E/P (emerged biomass / larval production) of 19.3% for *H. angustipennis* and 27.0% for *H. pellucidula*. These ratios are four times higher than those in SPEIR & ANDERSON (1974) determined for four kinds of black flies. However they are within the range JACKSON & FISHER (1986) determined for *Cheumatopsyche arizonensis* (LING, 1938), another species of Hydropsychidae.

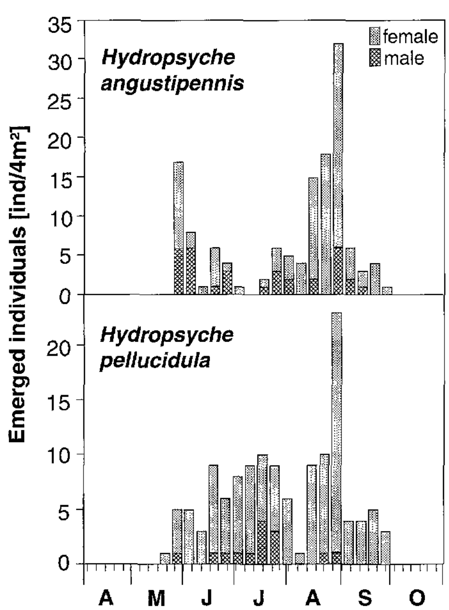

Fig. 5. Emergence pattern of *Hydropsyche angustipennis* (n = 133 ind.) and *H. pellucidula* (n = 130 ind.) during the investigation period from 10th April to 8th November 1989.

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